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RECOMMENDED WARTIME REFUSE DISPOSAL PRACTICE WITH PARTICULAR REFERENCE TO THE SANITARY LANDFILL METHOD OF DISPOSAL FOR MIXED REFUSE

C. C. Spencer

Public Health Service
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With Particular Reference to the Sanitary Landfill Method of Disposal for Mixed Refuse

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FEDERAL SECURITY AGENCY

UNITED STATES PUBLIC HEALTH SERVICE

THOMAS PARRAN, *Surgeon General*

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RECOMMENDED WARTIME REFUSE DISPOSAL PRACTICE

Necessary wartime modifications of customary practice in the collection and disposal of municipal refuse should not be permitted to violate standards established for the protection of the public health. With this in mind, current aspects of collection and disposal are discussed and the satisfactory operation of sanitary landfills is outlined.

Recent experiences in many United States communities indicate that wartime conditions have appreciably affected customary practice in the collection and disposal of refuse. Increasing shortages of labor and equipment replacements have resulted in a curtailment of these services in some areas, and wartime economies have been responsible for changes in the amount and character of the wastes produced. A rise in food prices may result in some reduction of garbage quantities such as occurred during the depression years. Similarly, the increased salvage value of waste paper and metal may be expected to reduce the amounts of these materials collected. In some cities equipped with refuse incinerators, the salvage of paper has already reduced the combustible content of the refuse to the point where increased amounts of auxiliary fuel have become necessary.

The extensive population shifts incident to the war have greatly increased the refuse disposal problem in some communities. At a time when an expansion of collection and disposal facilities is most difficult, these places are faced with the necessity of handling large additional amounts of refuse. Such communities are finding it impossible to provide new or additional incinerator capacity requiring large amounts of critical material more urgently needed in the armament program. It should also be noted that the changes in the amount and kind of refuse brought about by the war may be of a temporary nature and that the methods of dealing with these wastes should be designed only for the period of the emergency. Large capital outlay for permanent structures may not be so easily justified from an economic standpoint as it would be in the case of municipal incinerators having an expected normal useful life of 15 to 20 years.

In England, under condition of direct attack, more acute interference with refuse collection and disposal has developed. Bombing raids have resulted in accumulations of building rubble which must be carried away by collection forces that have been depleted in number by other emergency tasks. In many cases, collection routes have been blocked, necessitating the diversion of collection vehicles over poor roads and unsafe bridges to the disposal site.

The more common types of dry waste usually included in municipal refuse are shown in table 1. The quantities and unit weights indicated for each have been assembled from various sources. They are cited to emphasize the wide variation in quantity and costs which are experienced, and the need for each city to analyze the characteristics of its own refuse before attempting to adopt practices which have proved satisfactory elsewhere. The costs are given as reported and do not in all cases include the same individual items of expense. The methods used for estimating the amounts of refuse collected vary widely in each city and render it difficult to compute comparable unit costs.

TABLE 1

	Pounds per capita pe. day				Weight per cubic yard		Collection cost per ton, in dollars		Collection cost per cubic yard, in dollars	
	Summer		Winter							
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Garbage: Food waste from kitchen and market	0.30	2.3	0.2	1.2	800	1,300	1.00	8.92	0.61	1.37
Rubbish: Paper, wood, bedding, metal, glass, dirt, etc.	.20	1.8	.4	1.1	100	700	1.00	14.00	.....	.....
Ashes	.12	.2	1.9	2.2	1,150	1,400	.....	.....	.....	.....
Street refuse: Sweepings, dirt, leaves, etc.	.5	1.5	.5	2.0	800	1,400	.....	.....	.....	.....
Garbage and combustible rubbish combined	.7	3.9	.?	1.3	200	800	1.00	8.83	.62	1.22
Ashes and noncombustible rubbish combined	.1	1.1	.60	5.0	750	1,165	.67	2.52	.49	.98
All refuse combined	1.2	3.4	2?1	5.5	500	1,000	1.00	5.00	.25	1.53

PUBLIC HEALTH PROBLEMS

In the collection and disposal of municipal refuse, certain principles must be observed for the protection of the public health. Various practices in the field can be so administered as to satisfy these principles without being also economically acceptable. It is possible, however, to operate most systems now commonly used in such a way that the requirements for protection of the public health, safety, and convenience will be met without materially increasing operating costs.

The food content of garbage constitutes an attraction for rodents and insects. If accessible to them, it will result in their multiplication and spread. Rats are important agents in the spread of diseases such as plague and typhus fever. The fly problem is also increased by a failure to provide proper garbage handling facilities. The relationship of these insects to the transmission of intestinal diseases such as typhoid fever is recognized. In some cases, infected material, such

as sputum or dressings from the sick room, may be discharged with garbage. It is therefore essential to the protection of the public health that this material be stored in tight containers inaccessible to vermin from the point of production to the point of final disposal.

The materials ordinarily included in rubbish and ashes do not constitute a health hazard as in the case of garbage, and the need for care in handling them is therefore not so great. It may be necessary to store ashes in fireproof containers where facilities for cooling prior to storage cannot be provided.

COLLECTION

Garbage, rubbish, and ashes should be stored in separate containers regardless of the method selected for collection and disposal. This will be found advisable in cities collecting all materials in the same vehicle, and in those making separate collections.

In England, an intensive campaign to salvage metals and paper from household waste has resulted in the requirement that individuals separate paper, rags, metals, and other materials before placing them for collection.

Costs of collection will be found ordinarily to exceed the costs of disposal, and thorough consideration of this fact is essential to a proper engineering analysis of the problem. Cities which collect all classes of refuse together commonly report a substantially lower collection cost per ton or per capita than those cities which collect rubbish and garbage separately.

Combined collection is not feasible with all disposal methods. For instance, garbage used for hog feeding must be segregated from other waste materials. When the increased costs of separate collection are considered, however, it becomes difficult to justify hog feeding or other utilization of garbage by itself from an economic standpoint.

There are many cities which do not attempt to collect all forms of refuse but restrict their activities to garbage alone, or to rubbish alone, allowing private scavengers to collect garbage in the latter case. However, present tendencies in municipal cleansing are for the city to provide all refuse collection necessary to the maintenance of proper sanitary standards at a fixed charge rather than to rely upon individuals to maintain their neighborhood in a satisfactory condition. Fixed costs to the city remain about the same whether all service required is furnished or whether the householder is permitted to decide what portion of the service he desires to pay for and utilize. Collection either by contract or by municipal forces are satisfactory where competent municipal supervision is provided.

Regardless of the collection practice followed, it is recommended that each household be equipped with a hot dipped galvanized steel can for garbage. Substitute materials available at the present time

do not appear sufficiently resistant to garbage acids and abuse to show satisfactory wearing qualities. A capacity of 7 to 10 gallons appears adequate for the average family. The can should have a tight-fitting, locking-type of cover, and a slightly recessed bottom. For the capacities noted 26- to 30-gage metal has proved acceptable. Because of wartime restrictions, efforts are now being made by several Federal agencies to develop a satisfactory substitute for galvanized iron containers.

Provision of a small, adequately drained, wood or concrete platform for cans at each home will increase the wearing qualities of the cans considerably, an important item to be considered in the light of the current steel shortage. The construction of such platforms should be designed to avoid the creation of rat harborages. Garbage should be well drained before it is placed in the cans. Many communities require that garbage be drained, wrapped, and tied before being placed in containers. This practice has been found valuable in increasing container life and ease of collection, and may permit the use of other than steel containers. It is not feasible, however, in cities using hog feeding or reduction as a method of disposal. Rubbish may be stored in wooden barrels, boxes, or burlap bags.

Some cities require that householders place refuse at the street curb on collection days while others permit collectors to enter back yards and basements. The former method may be expected to show considerable economy in collection costs.

Collection vehicles should be equipped with covers or tarpaulins to prevent spillage, odors, and other nuisance complaints. It is doubtful that new vehicles especially designed for the purpose can be secured during the present emergency, and cities may be forced to adapt trucks intended for other purposes to this service. Reports indicate that trucks using a three-man crew have provided a most satisfactory service in many cities.

In residential districts, semiweekly collection of garbage should be regarded as the minimum desirable. Daily collection should be provided in commercial areas. More frequent collections may be required in summer. The attempts of some cities during the emergency to reduce the frequency of collection because of the scarcity of labor and lack of equipment may result in overloading of individual garbage storage facilities and cause a serious health hazard. Less frequent collections also tend to render the emptying of containers more difficult and can reduce the efficiency of collection. Arrangements should be made promptly to extend collection service to areas hitherto not served where a rapid population expansion due to war activity results in unusual accumulations of refuse.

It is important that municipal ordinances be provided to enforce

practices decided upon following consideration of some of the s-tions outlined above.

The distance which refuse must be hauled and, more particularly, the time required for hauling, are of prime importance in the cost of collection. The topography of the district, population distribution, and the lay-out of streets and alleys will all affect the type of vehicles used and the collection routes chosen.

DISPOSAL METHODS

A thorough consideration of collection problems will emphasize the advantage of selecting a method of disposal which can be located close to centers of population. Alternate costs of using one or several points of disposal should also be considered. Insofar as possible, collection vehicles should be diverted from main traffic routes and operated during off-peak hours of traffic flow. Among the more common methods for the ultimate disposal of one or more types of refuse, which may possibly be considered to meet present wartime conditions, are the following:

Hog feeding.—Recent surveys by the United States Public Health Service indicated that over 50 percent of the cities questioned disposed of all or a portion of their garbage by hog feeding. The survey also revealed a surprisingly high incidence of trichinosis among hogs which were fed uncooked garbage. Consumption of insufficiently cooked pork from such hogs is believed to be the chief source of human trichinosis, a serious disease resulting in gastro-intestinal disturbances, remittent fever, and muscular pain. Although frequently diagnosed incorrectly, trichinosis is reported most frequently from areas where large numbers of garbage-fed hogs are raised.

Efforts to prevent the spread of trichinosis in man have resulted in an amendment to the United States Interstate Quarantine Regulations stipulating that no garbage may be shipped interstate for hog feeding unless first cooked at 212° F. for 30 minutes. New York, Washington, Oregon, and Kentucky have State regulations stipulating that garbage be cooked before being fed to hogs. The Dominion of Canada also has regulations of this type. In Los Angeles, hog feeders are conducting extensive studies of a so-called "pasteurization" of garbage which seem to indicate that cooking impairs some of the food value of the material. Further study on this question is needed.

In England, several plants for the cooking of garbage used for hog feeding have been constructed during the war as an aid in increasing the home production of pork. The Borough of Tottenham processes kitchen waste in steam-jacket vessels for 2 hours at 203° F. It is then cooled and sacked for livestock feed. Some of the objections to

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cooking by hog raisers can probably be overcome by having the inedible portions manually separated before processing.

Only about 50 percent of the garbage produced in homes and restaurants can be consumed by hogs. Consequently, other means of disposal must be provided for inedible garbage, such as melon rinds and citrus fruits, as well as for rubbish and ashes. The economy of combined refuse collection is therefore not adaptable to this method of disposal.

The prevalence of diseases other than trichinosis among garbage-fed hogs is frequently the cause of their being condemned in well-inspected packing houses. This sometimes results in lower prices being paid for such animals. In addition, disease conditions on farms feeding garbage may be responsible for considerable financial loss.

Reports from Los Angeles indicate that the food value of garbage for hogs is apparently decreasing since 60 pounds of pork was obtained per ton of garbage fed in 1923 compared with 30 pounds in 1940. Fifty to 75 hogs are usually provided per ton of garbage received daily. Approximately 1 acre of land is required for 50 hogs. The disposal of uneaten garbage and hog manure constitutes a real problem. Ordinarily it is buried. Hog farms will usually give rise to nuisance complaints unless located at a site well removed from centers of population.

Grinding of garbage for discharge to sewerage system.—This method may be used in cities which discharge untreated sewage into large bodies of water, or to those equipped with sewage treatment plants designed for handling garbage. It is adaptable to the disposal of garbage only, and the practice to be followed will depend upon local conditions and facilities available.

Incineration.—The incineration of garbage and combustible rubbish has received considerable favorable attention during recent years. There also has been some interest in plants equipped to dry and burn sewage sludge combined with garbage and refuse. The production of electrical power from the burning of combustible rubbish and garbage has contributed to lower incineration costs in some places. From the standpoint of sanitation, well-operated incinerators are one of the most satisfactory methods of disposal.

Incinerators should be operated as continuously as possible at their design capacity for the best results. Ordinarily they should not be expected to operate more than 144 hours per week and should be designed for daily loads at least 150 percent of average. Since refuse trucks do not arrive at the plant uniformly during the 24 hours, facilities should be provided for the storage of the material at the plant to permit continuous and uniform stoking of the furnace with refuse.

Variations in moisture or combustible material in the waste will cause operational difficulties. The salvage of paper and other combus-

tibles rendered necessary by the war is already affecting the operation of incinerators by making it necessary in some cases to use auxiliary fuel. Cities with incinerators must provide other methods for the disposal of incombustible refuse.

Large changes in the population of some cities because of the war have resulted in excess amounts of waste which cannot be handled in existing incinerators. Because of the large investment required and possible temporary nature of the population increase, the construction of incinerator additions would be of doubtful economy regardless of the critical materials required for construction. The difficulty of operating incinerators in a manner satisfying black-out requirements must also be considered.

In order to prevent odor and smoke nuisance from an incinerator, all combustion gases should be passed through a furnace temperature of 1,400° F. average and 1,250° F. minimum. Incinerators have been variously reported to produce from 15 to 50 percent ash from the material burned. This is commonly used for fill but creates an additional disposal problem and a need for rehandling in crowded areas. Frequently dumps consisting solely of incinerator residue have been found to harbor large numbers of rats.

The following items must be considered in computing incinerator operating costs:

Interest and amortization (approximately 10 percent of total first cost each year).
Labor.
Auxiliary fuel.
Electric power required for operation.
Repairs and replacements.
Water.

Revenue from power when produced must be considered in relation to the above costs.

Reduction.—The process of reduction consists of cooking garbage under steam pressure for the recovery of grease and tankage. Solvents may or may not be used. Separate collection is required.

Plant construction is costly and the process has generally been used only in cities over 100,000 population. For many years the low market value of the salvaged materials and the high cost of operation have discouraged the use of this method.

Open dumps.—The dumping of mixed refuse in isolated spots has been widely used. As long as sufficient low-cost land is available within a reasonable distance, the practice will have many advocates for reasons of economy.

The objections to it are so numerous that most cities are realizing the necessity for finding other methods of disposal. The gradual urbanization of the country is making it increasingly difficult to find acceptable dumping grounds without excessive hauls. Open dumps

are not satisfactory to health authorities since they provide ideal breeding places for rats and other vermin, and usually constitute both a fire hazard and a smoke and odor nuisance. In addition, the nuisance produced by an open dump may be expected to result in a loss of property values in the vicinity. Recently military authorities on the Pacific coast have ordered the abandonment of such dumps because their frequent fires produced interference with black-out requirements.

Sanitary fill.—Sanitary fill, also known as "cut and cover" in this country, and as "controlled tipping" in England, was developed in an effort to overcome the objections to the insanitary open dump. The operation consists in dumping a mixture of garbage, rubbish, and ashes, and covering it promptly with a layer of earth to exclude rodents and other vermin, and to prevent the escape of odors, or the outbreak of fire.

Experience with the practice on the Pacific coast, in New York City, and elsewhere has indicated that where suitable land is available this method of refuse disposal is economical and has a definite value for the reclamation of otherwise waste or useless land. The New York World's Fair of 1939–40 was constructed on land reclaimed by this method.

In connection with a suit brought against the city of New York in 1939 concerning the establishment and usage of such landfills in the Borough of Queens, the Surgeon General of the United States Public Health Service was requested by the court to appoint a board of experts to study the health aspects of the landfills under consideration. The board comprised the following members: Dr. M. J. Rosenau, Dr. E. L. Bishop, Dr. Huntington Williams, Dr. K. F. Maxcy, and Civil Engineer R. E. Tarbett. The board concluded as follows:

> There is a sharp distinction between the regulated landfill and the ordinary unsightly town dump which is mostly made up of ashes and dry refuse, but which may also contain some garbage. There is frequently no planning or supervision exercised so that these dumps are generally unsatisfactory. Sanitary landfills, however, differ from the usual dumps in several important respects:
>
> First, the mixed refuse contains garbage and organic matter subject to decomposition; second, the deposited refuse is compacted by mechanical equipment; third, the deposit is covered as rapidly as possible by a layer of earth; and fourth, the operations are supervised according to practice based upon study and experience.

The study of the board was confined entirely to the questions of the possible dangers to the public health or safety arising from the landfills established in the Borough of Queens, and the following points were considered:

1. The conditions favoring the propagation and harborage of rats and other rodents.
2. The conditions favoring the breeding of insects such as flies and mosquitoes.
3. The possibility of fire originating in the combustible material in the fill.
4. The weight-bearing value of the completed fill for future building operations.

The following findings and recommendations were made by the board:

In the opinion of the board, based upon its observations and studies, there were no present conditions at the landfills which endangered the public health or safety. On the contrary, the board was convinced that certain potential public health hazards were removed by the landfills, as filling is one of the best methods of rat and mosquito control for swamps and marshes. The board was also of the opinion that no future dangers to the public health or safety would arise so long as sound sanitary practice was continued.

In 1922, after a careful study of a somewhat similar method of refuse disposal in England, the British Ministry of Health indicated its approval by issuing suggestions for maintenance of such disposal areas. English investigators have also reported that the temperatures created within the fill by decomposition are sufficiently high to destroy pathogenic bacteria and fly larvae which may be present in the material before covering.

Certain economic advantages of landfills when compared to other disposal methods are evident. Combined refuse collection is permissible and disposal sites may be located close to centers of refuse production without creation of nuisance conditions. Several disposal sites may be in use simultaneously for convenient periods of time.

The equipment required is not excessive in cost and is of general utility. Many communities may own draglines, power shovels, or bulldozers which can be adapted to the purpose. Daily variations in the amount of waste affect operations to a minor extent. Wartime salvage programs and unburnable material create no special operating difficulties. Fire hazards are small, thus rendering the method acceptable during black-outs. Appearance of the completed fill has no deleterious effect on nearby property values.

The approximate costs per ton of landfill disposal are reported from various localities as follows:

New York, N. Y.	$0.28
Portland, Oreg.	.39
Seattle, Wash.	.30
Cristobal, C. Z.	.54
English cities	.62

In spite of their advantages, there are certain aspects of landfills which will render their use inadvisable or impossible in some cases.

Unless extreme care is used in operation, rats may be attracted by small uncovered deposits of refuse and find shelter in nearby buildings or vegetation. Rats were at one time reported near the San Francisco fills in large numbers. Perhaps the most important factors in the control of rodents near fills are the original degree of compaction afforded the refuse and cover, and the maintenance provided following completion of filling. Improper coverage and compaction often result in the formation of voids which provide ideal harborage for rats.

Unequal settlement resulting from improper compaction may cause additional cracks and openings for rats sometime after the fill is believed completed. Clay and similar material should not be used for cover since rat burrows are more easily constructed in it than in more sandy material. The heaviest obtainable equipment should be used for compaction.

An increased number of crickets, cockroaches, water bugs, and sow bugs have also been reported in buildings adjacent to some sanitary fills, but no evidence is available concerning the responsibility of the fills for this condition.

Drainage from landfills has been shown to have a high oxygen demand and may cause pollution of water courses or of beaches when the fill is deposited near the shore of bodies of surface water. It is possible that improper location of fills may also result in pollution of ground water.

Relatively little is known regarding the chemical, biological, and physical changes which take place in the material deposited in landfills. Garbage buried deeply has been uncovered many years later almost unchanged by the passage of time, while the same type of material deposited near the surface apparently is decomposed rather completely in as short a time as 30 months. However, it should be remembered that the amount of garbage contained in mixed refuse is less than 15 percent by weight during a considerable portion of the year. The experience with buried refuse will therefore not be strictly analogous to that with garbage.

During the construction of the World's Fair site in New York, organic waste which had been buried for many years easily caught fire when uncovered.

The characteristics of landfills of various ages in New York has recently been the subject of extensive study by the New York City Division of Sanitation, New York University, and the Work Projects Administration.

It appears from the data secured in this study that the changes taking place in landfills are less extensive than was hitherto believed. Decomposition of organic material appears to proceed very slowly but inspection of refuse in place for varying periods shows a progressive disintegration with time and the formation of a dark granular substance retaining a strong odor but otherwise greatly modified from the material originally placed.

Various studies show that temperatures after placement of fill rise rapidly to between 130° and 150° F. in about 4 days at a depth of 3 feet below the surface. After remaining at this point for 60 days or more, temperatures fall gradually until they become stabilized near air temperature after about 10 months. Temperatures at a 14-foot

depth average considerably below those at 3 feet in some cases. Such conditions are not well suited to rapid bacterial decomposition.

Authoritative opinion is divided on the utilization of completed landfills. The establishment of parks and recreational areas on them appears to have been generally satisfactory. The Seattle building department also permits dwelling construction on fills, and reports no difficulties with uneven settlement.

Where heavier buildings are to be constructed on fills it appears necessary to carry the foundation through the fill or to use reinforced concrete mat foundations. Piling is ordinarily not recommended for reasons of economy, and also because settlement of the fill will leave structures supported in this manner above the surrounding ground level. In several cases this has resulted in the cracking of nearby pavements and the creation of rat harborages. Such differential settlement is, of course, not confined to sanitary fills.

Settlement at New York is stated to approximate 20 percent in the first 6 months following compaction, and 10 percent additional at the end of 2 years. English practice is said to result in settlement of 10 to 16 percent. The amount and rate of settlement will depend to a large extent upon the amount of compaction provided and the depth of fill, and will probably vary greatly from place to place. A large proportion of the final settlement may occur in 6 months to a year. Uneven settlement of the surface may be caused by the presence and improper placement of bulky rubbish and failure to provide a well-mixed refuse. Large accumulations of tree branches should be burned before placing them in the fill. Seattle reports that fills made of summer refuse will settle 12 inches in 6 months, compared to some 6 inches with winter refuse. In cold climates, excavating operations will be considerably hindered by frozen ground during the winter. It may therefore be necessary to excavate cover material during the summer for later use during cold periods.

Certain gases generated in fills, such as methane and hydrogen sulfide, may constitute a possible hazard where basements or other closed spaces are constructed in fill material.

Water pipes passing through fills may require special construction to protect them from settlement and contamination. This will also apply to sewer and gas lines.

In selecting sites for landfills, low areas such as ravines, swamps, and abandoned borrow pits are regarded as particularly suitable topography provided fill operations do not obstruct natural drainage courses. Earth should be available for cover materials, sandy soil being most desirable. Attempts to use gumbo clay for cover have not been successful because this material is subject to shrinkage cracks which prevent proper sealing of the deposited material. It is also undesirable from the standpoint of rodent control as discussed above.

Fills should not be made where springs exist or be so located as to obstruct natural drainage channels. If possible, sites should be chosen so that prevailing winds will carry any occasional odors away from built-up areas. Odors have been observed over 1,000 feet to windward with a 15-mile-an-hour wind. In most cases it is believed odors will not be noticed more than 300 feet from the scene of operations.

The choice of a disposal site should be governed largely by the distance from sources of waste and by the availability of suitable access roads, bridges, etc. Refuse trucks should not be routed over main traffic arteries where this can be avoided.

An area of 0.75 to 1.5 acres will be required each year for a population of 10,000 where the refuse is placed in layers having a compacted depth of 6 feet.

Current practice in the operation of landfills varies with the size of the city, conditions at the site, and equipment available. In general, it is necessary to compromise between the fact that decomposition is most rapid at shallow depths and the desire to keep fill area at a minimum per cubic yard of refuse in order to reduce the amount of cover material needed. Relatively shallow layers of refuse have been found to settle more uniformly, thus providing a more level surface for the operation of trucks and minimizing the amount of supplemental regrading necessary.

The board of experts appointed by the Surgeon General in the New York case mentioned previously made the following recommendations on landfill operation:

1. The disposal of wastes by the landfill method should be planned as an engineering project. Operations and maintenance should be under the direction of a sanitary engineer.

2. The face of the working fill should be kept as narrow as is consistent with proper operation of trucks and equipment in order that the area of waste material exposed during the operating day be minimal.

3. The exposed surface should be covered with earth as promptly as is consistent with proper operation, and at the close of each day's operation both the surface and the face of the fill should be completely covered, the object being to make a closed cell of each day's deposit.

4. Sufficient standby equipment should be provided to prevent delay in covering, because of break-downs or peak loads.

5. Waste building material, concrete, or other bulky waste material which may furnish rat harborage should not be used for the final surface or side slopes, but should be promptly incorporated within the fill.

6. The final covering for surface and side slopes should be maintained at a depth of approximately 24 inches.

7. In case the finished fill has a boundary side slope, the toe of the slope should terminate in a sand-and-gravel-filled ditch. This will prevent raveling of the toe with exposure of some of the waste material, will prevent the burrowing of rodents, and finally will obviate puddles by permitting seepage from the fill to be absorbed into the ground.

8. Spraying of the exposed waste material and adjacent surfaces should be used when necessary to allay dust.

9. As a rule, the layer of refuse should not exceed an average depth of about 8 feet after compacting. Where deeper fills are necessary the filling should be carried on in stages.

10. Control over the blowing of papers should be adequately maintained by the use of movable snow fencing.

11. While the maintenance of proper earth covering as hereinbefore recommended will to a large extent prevent fires, water under pressure should be available for fire-fighting purposes. If scavengers are tolerated, they should be adequately supervised.

12. All collections of surface water resulting from these landfill operations should be drained, filled, or treated with effective chemicals so as to prevent mosquito production or allay disagreeable odors.

13. Where necessary, effective steps should be taken to prevent floatage of waste material into open water.

14. Inspection for and control of rodents should be maintained until fills are stabilized.

15. After the active period of the filling operations is completed, a maintenance program should be continued until the fill has become stabilized so as to insure prompt repair of cracks, depressions, and erosion of the surface and side slopes.

16. Studies of the varied problems involved in landfill operations should be continued and should include researches into the biological, chemical, and physical activities, as well as the engineering, economic, and administrative aspects of the subject.

The British Ministry of Health Precautions for Controlled Tipping correspond in large part with the above recommendations. However, the British are reported to exclude a large portion of putrescible material from some of their most successful tipping operations. They recommend that glass be broken and raked to the bottom of the fill together with flattened tin cans and metals before cover. It is thus hoped to avoid occasional projection of these materials above the fill surface where they will constitute a hazard in the future use of the fill.

The surface slope of finished fills should approximate 1 percent. Supplementary grading will usually be necessary to secure this slope and permit satisfactory drainage. It is recommended that side slopes of completed fills be kept rather flat to permit proper compaction and to reduce erosion. A slope of 5 horizontal to 1 vertical has proved desirable in sandy soils.

Thorough compaction of fill material is also important as it assists in obtaining uniform settlement and reduces the amount of cover required. Depths of fill greater than that recommended above are apt to result in difficulties due to uneven settlement.

Although rats will ordinarily not burrow more than 12 inches, a final cover of earth 24 inches in depth is believed necessary on surface and face of fills to compensate for uneven settlement and grading.

Where proper cover is provided, the use of disinfectants on landfills is not considered essential but it is practiced in some places. New York City sprays exposed refuse several times a day with an orthodichlorobenzene preparation, and some west coast cities use a cresol solution at the rate of 1 gallon per cubic yard of refuse. It has been

suggested that the continuous addition of water to refuse during placement would assist in the stabilization of the fill and reduce the nuisance of blowing papers and dust.

A variety of equipment is in use for the operation of landfills. Draglines are especially suitable for excavating cover material and placing it for final spreading and compaction by bulldozers. In New York City 20-ton bulldozers are used to force forward and compact refuse dumped by trucks 20 to 30 feet from the working face of the fill. The surface of the material is carried to a height approximately 30 percent above the desired final elevation. Recently the city has adopted a strip operating system at some fills which consists in carrying the refuse and cover forward as an embankment 100 feet wide at the top. This results in a reduction of the amount of refuse exposed at any one time and confines bulldozer movements to a small area with a consequent increase in compaction. Some economy in the amount of cover necessary is also said to result. Following the completion of one strip, a second is placed beside it. (Figure 1.)

Fresno, Calif., uses a system of trenches and cover suitable for level areas which uses no compaction other than that which can be accomplished by dropping the dragline bucket on refuse in place. This system has been in use for more than 5 years with reported satisfactory results. In operation, earth from a trench 30 to 70 inches deep is banked at one side to form a ramp from which trucks may dump into the first excavation. A second trench is then made next to the first to provide cover for the refuse deposited. Succeeding trenches need to be only deep enough to provide the amount of cover desired. It has been found desirable to make the area filled in this way approximately square to reduce the amount of equipment movement necessary. Alfalfa planted on the cover after a few months is reported to flourish. (Figure 2.)

A similar method is reported from Rochester, N. Y., where trenches 25 feet wide and 8 feet deep were filled to a depth of 6 feet with refuse and covered. Refuse was then spread over the entire area and covered with material originally excavated from the trenches.

During the war emergency draglines may be difficult to procure and cities planning to utilize sanitary fill as a method of disposal may find it necessary to use power shovels, trenching machines, or equipment which can pick up and carry loads of earth and refuse. Tractor scrapers provide an extremely economical method of earth moving on short hauls and should be particularly adaptable to provide the necessary cover material for landfill operations.

The degree of compaction afforded the fill by the operations of heavy tractors and trucks on its surface is considered to be sufficient without the use of rollers.

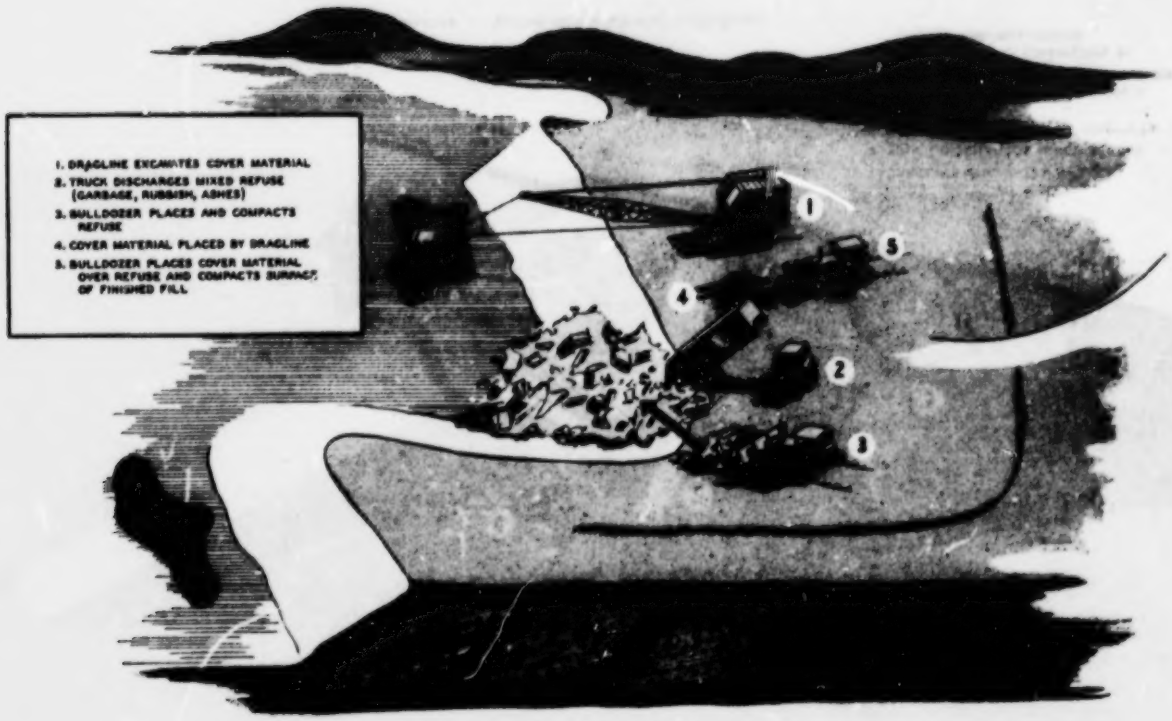
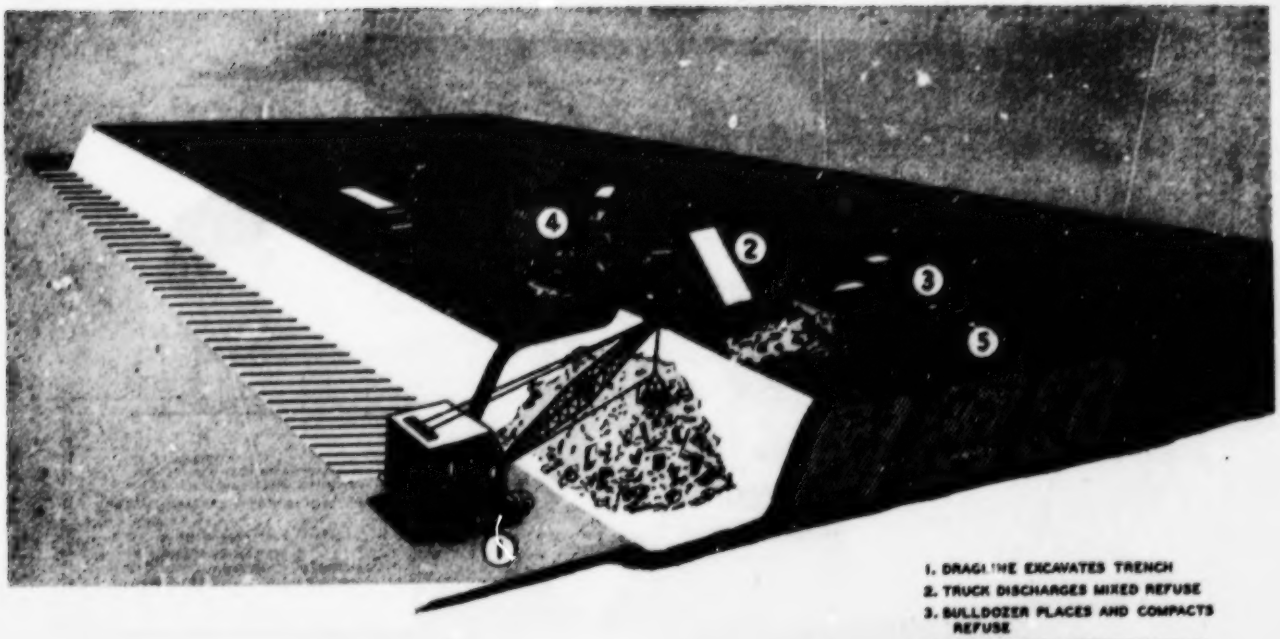

1. DRAGLINE EXCAVATES COVER MATERIAL
2. TRUCK DISCHARGES MIXED REFUSE (GARBAGE, RUBBISH, ASHES)
3. BULLDOZER PLACES AND COMPACTS REFUSE
4. COVER MATERIAL PLACED BY DRAGLINE
5. BULLDOZER PLACES COVER MATERIAL OVER REFUSE AND COMPACTS SURFACE OF FINISHED FILL
1
5
4
2
3

FIGURE 1.—Sanitary fill operation for low areas.



1. DRAGLINE EXCAVATES TRENCH
2. TRUCK DISCHARGES MIXED REFUSE
3. BULLDOZER PLACES AND COMPACTS REFUSE
4. COVER MATERIAL FROM TRENCH IS PLACED OVER REFUSE BY BULLDOZER
5. FINISHED FILL IS COMPACTED BY TRUCKS AND BULLDOZER

FIGURE 2—Sanitary fill operation on level ground.

For communities of less than 20,000 population, equipment with a 1-cubic yard capacity which can pick up and carry earth and refuse, mounted on a track-laying tractor, would be sufficient for all fill operations. For larger cities the use of power shovels or draglines in combination with heavy bulldozers will be preferable.

Under wartime conditions it will be necessary for each community to demonstrate considerable ingenuity in adapting sanitary fill to its own needs in a manner that will eliminate nuisance conditions. Skilled supervision will be required and should be continued for a considerable period after the completion of the fills to insure that minor regrading and trimming is carried out as it becomes necessary.

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